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28.

Further Studies on the Light Sensitivity and Behavior of the Mexican Blind Characin.

C. M. Breder, Jr.
New York Aquarium,

&

E. B. Gresser,
New York University College of Medicine (Department of Ophthalmology).

(Plate I; Text-figures 1 & 2).

Introduction.

It has been shown by Breder & Gresser (1941) that the blind individuals of the Mexican Characin *Anoptichthys-Astyanax* series are light sensitive. This was made evident by their behavior in a gradient trough in which they showed themselves to be slightly but clearly light negative. No attempt had been made at the time that report was prepared to delimit the mechanism of this discriminatory power. The cystic form of the vestigial remnant of eye structure and its heavy investing pigment layer seemed to preclude its use as an organ of light detection, Gresser & Breder (1939) and Breder & Gresser (1941).

Experiments.

As one step toward understanding this mechanism of light perception a normal blind specimen was selected, and the vestigial eye structures were removed. Healing was rapid and satisfactory and no gross differences could be detected in its behavior.

Two tanks were employed, each with one-half light and one-half dark as described in Breder & Gresser (1941). Into one was placed a normal blind fish as a control and in the other the experimental fish. As in the earlier paper, counts were made of the frequency of appearance of the fish in the lighted halves of the tanks. The data obtained, which covered nearly a month, are given in Table I. This table indicates clearly that the experimental fish showed no bias to one compartment, the actual distribution being within 0.29 − of the expectation. The control, on the other hand, agreed well with the experiments previously reported, and fell to 13.71 + of expectation; showing that much bias to the dark half of the tank. Expressed in terms of percentage of random expectation with 100% representing pure randomness, above it light positiveness and below it light negativeness, the following figures represent the situation:

Experimental	100.58%
Control	72.58%

It is thus evident that the light detection of these fishes is lodged in some retention of function in the optical vesicle, despite its histological appearances to the contrary. The test fish, at this writing, is still living and apparently not in the least inconvenienced by its loss of ability to detect light. It cannot be separated from the others on a basis of behavior except by some formal procedure as above outlined. In previous papers concerning the ocular morphology of these blind fish, various types of undeveloped and mal-developed eyes were shown. Based on histological appearances, very little if any function was attributed to any eye of the cystic type even if a few scattered retinal elements were present. It was understandable that eyes architecturally intact but of comparatively microphthalmic proportions could be serviceable under restricted conditions and that anophthalmic vestiges predicated complete blindness. The present study involving individuals with defective ocular structures but in which some, if sparse, rods and cones are present leads to the inescapable conclusion that there is some subservance to light sensation. However, it remains for further behavior experi-

ments followed by studies of histological preparations to determine the least number of retinal elements necessary for light sensation.

If the percentage of light avoidance of the control be compared with those reported by Breder & Gresser (1941), it is found that the present value of 72+%, compared with 62+% of its earlier tested tank mates and with 80−% of the larger fish taken directly from La Cueva Chica, places this fish roughly half way between those two groups. In reference to the latter values the following was stated in the earlier paper. "This difference of 17% may actually be significant. The cave fish were larger than the others and possibly overlying tissues of greater consequent thickness may account for the difference, or it may be that there is an increased avoidance to light in subsequent generations." Since those experiments were made the fishes reared in light for five generations (62+%) have grown so as to just about half close the size difference between them and the individuals from the cave (80−%). Consequently the lessened avoidance to light is about proportional to their growth (72+%). This suggests strongly that of the two quoted alternatives the first would seem to be the true one. In other words, it seems clearly indicated that the amount of overlying tissue determines to a considerable extent the reactivity of these fish to light. Further studies on much smaller specimens would go far to establish this view.

In order to better understand the normal unrestricted behavior of these fishes, an out-door pool was established in which approximately one-half was darkened so as to form a "cave" into which entry could be made from under water only. The entrance was provided with a light trap so that a true cave-like darkness could be obtained. This portion of the pool was roofed over and buried under about six inches of soil in which trailing vines were planted. The general arrangement and details of construction are given in Text-figure 2 while Plate I shows how the finished structure appeared.

Both blind "5th generation" and tank-raised normal river fish were placed in this pool and allowed to act according to their normal instincts. The trap door in the roof of the "cave" was padlocked and not opened until the termination of the experiments. Food was admitted to the "cave" through a small hole which was otherwise kept corked. More food was placed in the cave than in the lighted portion in order to prevent any possible bias to the outside based on hunger. Water was introduced only to make up for evaporation. This drained from another pool into the darkened portion through a light trap of loose rocks and gravel. From here it flowed through the cave and out into the lighted portion, simulating so far as possible the conditions in La Cueva Chica (see Bridges, 1940). Water lillies and *Nitella* grew in the lighted portion. In this brightly sunlit pool shade was provided by an offset in the cave wall from which the lillies grew and which was further shaded by a large *Cyperus* plant so that fishes would not necessarily be driven into the cave for the mere want of shade. As noted above, the water used drained from another well-seasoned pool which was being used for other fishes. This pool, shown in connection with other matters by Breder (1939 and 1940) and described in detail therein, drained into the new blind fish pool from its northeast corner.

TABLE I.

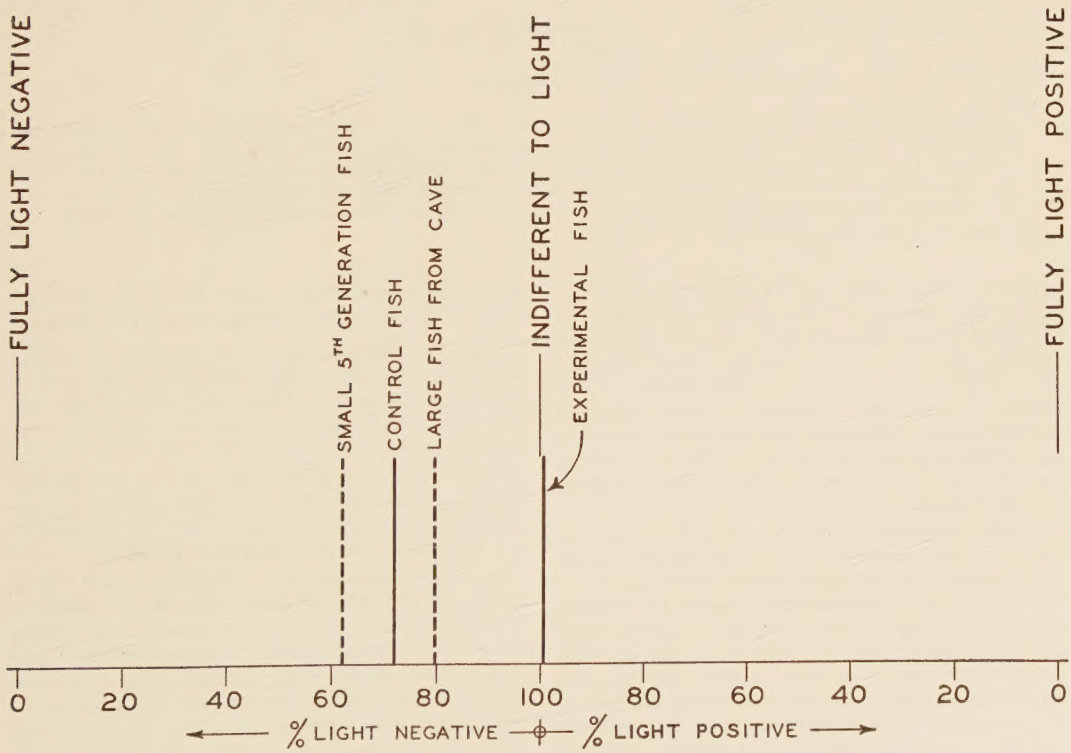
Exp. No.	Date 1941	Hour	Number of observations in light Fish No. 33	Fish No. 34
1	5/28	4:00 p.m.	48	32
2	5/29	9:30 a.m.	47	40*
3	5/29	4:30 p.m.	51	20
4	6/2	10:40 a.m.	36	39
5	6/2	4:30 p.m.	54	19
6	6/3	9:00 a.m.	53	27
7	6/3	4:15 p.m.	8	44
8	6/3	——	32	36
9	6/4	8:40 a.m.	56	35
10	6/4	4:45 p.m.	56	36
11	6/5	9:25 a.m.	65	35
12	6/5	4:25 p.m.	57	37
13	6/6	9:30 a.m.	64	27
14	6/6	4:45 p.m.	60	46
15	6/7	10:30 a.m.	55	34
16	6/7	4:55 p.m.	58	34
17	6/8	11:15 a.m.	55	26
18	6/8	5:00 p.m.	50	29
19	6/9	10:00 a.m.	60	47
20	6/9	4:10 p.m.	50	40
21	6/10	——	36	37
22	6/10	——	58	33
23	7/1	9:45 a.m.	44	46
24	7/1	4:45 p.m.	38	34
25	7/2	10:15 a.m.	51	43
26	7/2	4:30 p.m.	39	37
27	7/3	9:45 a.m.	52	34
28	7/3	4:45 p.m.	62	50
29	7/4	11:00 a.m.	72	39
30	7/4	3:30 p.m.	56	37
31	7/5	11:00 a.m.	63	44
32	7/5	3:00 p.m.	60	57
33	7/6	11:25 a.m.	38	34
34	7/6	4:50 p.m.	32	34
35	7/7	10:20 a.m.	44	40
36	7/7	2:30 p.m.	10	41
37	7/8	10:30 a.m.	32	28
38	7/8	2:30 p.m.	23	18
39	7/9	9:00 a.m.	74	44
40	7/9	3:30 p.m.	54	40
41	7/10	9:30 a.m.	73	46
42	7/10	——	86	25
			2112	1524
		Average	50.29−	36.29−
		Maximum	65	74
		Minimum	8	10
			% of Expectation	
		Average	100.58−	72.58−
		Maximum	130	142
		Minimum	16	20

* Each experiment represents 100 notations at 5-second intervals except the figure marked which was 75 and recalculated. There were 30 notations in light of the 75. Most of the actual readings were made by Mr. Max Recher.

The latter had been originally built for another purpose, see Shlaifer & Breder (1941).

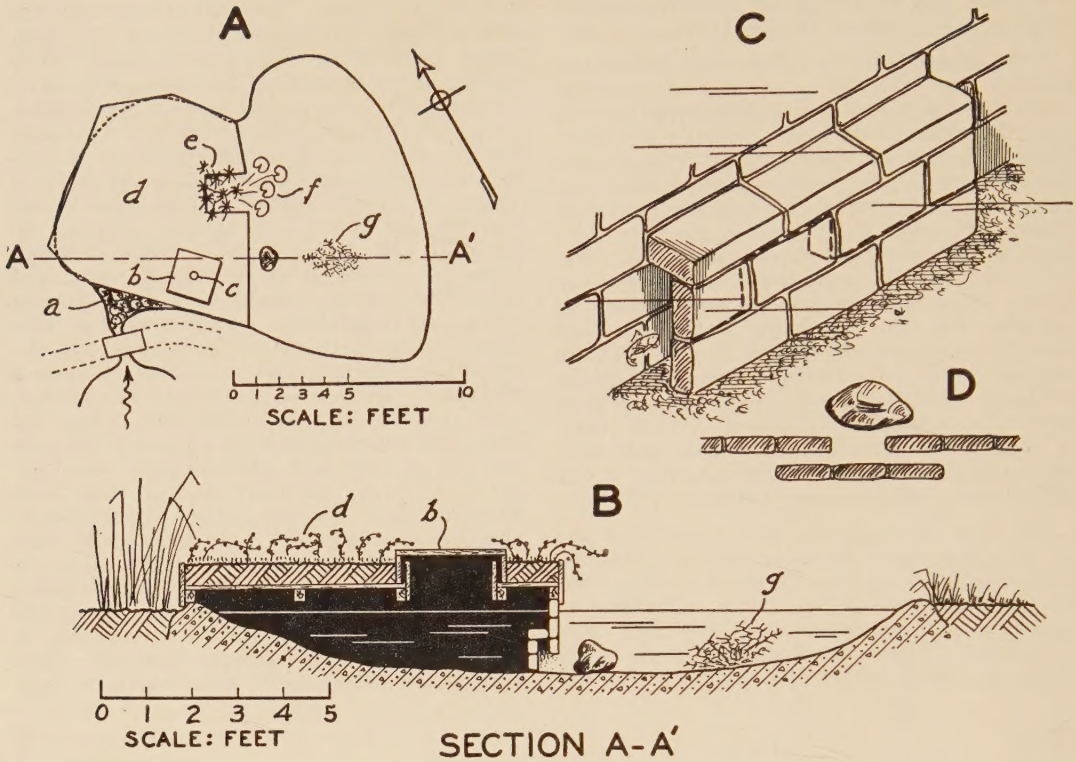
Data on temperature differentials and similar matters are given in chronological order in Table II. The fishes were all introduced into the lighted portion of the pool. Initially two blind fishes were placed in the pool to test if they could stand the early spring temperatures. In less than twenty-four hours these fish found the cave entrance and spent much time in the cave from then on, but wandered in and out at will. Apparently it took no longer time than this for them to learn their way about in the area of this pool for after the first day it was noted that they hardly ever struck objects and they would go in and out the somewhat tortuous entrance touching nothing. Since they show no evidence of distance reception, as noted by Breder & Gresser (1941) it would appear that they can satisfactorily learn the terrain of about one hundred and fifty square feet of area, which the pool covers, in that time.

In order to determine how much time was spent in and out of the cave, periods of observation were made on May 26 which cover a total observational time of three hours. The times of entrance and emergence from the cave were calculated. It was found that 83.3+% of the time was spent within the cave and 16.6+% in the lighted pool. This agrees well with the data of Breder & Gresser (1941) and that given herein in Table I. The present figure, while slightly higher than any of the others, is based on relatively few observations and has been necessarily calculated on a somewhat different basis. Further work of this nature could not be continued when more fish were introduced for a variety of purely practical reasons. Also it was subsequently found that other influences so modified this light avoidance reaction, which were not present in the laboratory work, that additional readings would have been without value. As it developed it was found that these influences could be readily understood and described but did not lend themselves easily to a statistical approach or analysis in this outdoor pool. Usually a few blind fish could be seen but there were long periods when all were in the cave and equally long ones when all were out of the cave. When the normally visioned river fishes were introduced on June 2, they also partook of this variation in habit. In their case, with marked schooling habits, it was clear that the activities of one individual had a sharp bearing on the others. Here, as in aquaria, they would attempt to school with a blind fish wandering by but soon gave up to return to their own apparently more satisfactorily behaving eyed com-



Text-figure 1.

Comparison of behavior between experimental and control specimen (shown in solid lines) together with the data of Breder & Gresser (1941) (shown in dotted lines) in terms of expectancy of random movement.



Text-figure 2.

Construction and details of experimental "cave." **A.** Plan of pool and cave as constructed. **B.** Section through pool and cave. **C.** Light trap as seen from inside cave. **D.** Plan of light trap. **a.** Loose stones and gravel to form light trap and block fish exit at point of inflow to pool. **b.** Trap door to cave. **c.** Corked hole in trap door for feeding and temperature reading. **d.** Roof of cave composed of flooring on stringers covered with soil and planted with vines. **e.** Large *Cyperus* plant. **f.** *Nymphaea.* **g.** *Nitella.*

panions. This plus the large areas involved apparently prevented the results disastrous to the blind individuals noted by Breder & Gresser (1941). At least at no time was anything seen that could have been interpreted as an attack on the blind by the normal eyed fishes. At times the addition of water would cause all to rush into the outflowing stream and enter the cave, where presumably they sought the blocked inflow from the other pool.

These effects were variable and at first puzzling but it soon appeared that the causes lie in temperature differentials between the cave and the open pool. For example there was a marked tendency for all the fishes to be out in the open in the daytime and to retreat to the cave at dusk, both eyed and blind alike. During the daytime the open pool would warm under the influence of solar radiation and rise several degrees above the cave temperature while at night it would drop below that of the cave which because of its cover did not lose its temperature nearly so fast. A study of Table II will indicate how these varying seasonal and diurnal temperature changes effected the relationships of the water temperature in the cave to that in the open pool. The results may be summarized as follows:

1. If the temperatures were identical, or nearly so, the fish would move in and out freely, usually with the majority of blind fish out of sight and the eyed specimens in a compact school in the lighted pool.

2. A difference of as little as 1.5° F. between the cave and the open pool would cause practically all to be in the warmer section, independent of time of day or brightness of light.

3. Water entering from the other pool would have various effects dependent on whether it was warmer than that in the cave or not. If the cave was notably cooler than either pool the water first passing into the lighted portion and cooling it would first prevent the fish from entering the cave and later as the cave warmed from the new water and the open pool cooled they would all enter, stimulated both by flow and temperature.

Many of both types of fish were evidently gravid during the middle of summer but it is doubtful whether any spawning took place as the

TABLE II.

Temperatures and related data.

Date	Hour	Water temperatures °F. Cave	Pool	Max.	Min.	
May 23	9:00 p.m.	—	73	—	—	2 cave fish in pool
24	7:00 p.m.	—	—	70	64	
25	7:00 p.m.	—	—	65	58	
26	10:30 a.m.	62	69	—	—	
	4:00 p.m.	60	67	—	—	
	7:00 p.m.	—	—	69	57	
29	8:00 p.m.	—	—	77	66	
30	3:00 p.m.	66	67	72	62	10 cave fish in pool
31	8:00 p.m.	—	—	74	60	
June 1	4:00 p.m.	63	62	—	—	
	6:00 p.m.	—	—	66	61	
2	8:00 p.m.	65	65	72	61	9 river fish in pool
3	8:00 p.m.	—	—	75	61	
4	6:30 p.m.	—	—	70	61	
July 14	3:00 p.m.	69	73	—	—	
18	8:00 p.m.	—	—	75	67	
20	8:30 p.m.	—	—	78	63	
22	7:45 a.m.	69	67	—	—	
	8:00 p.m.	69	73	78	62	
23	7:45 a.m.	70	69	—	—	
	8:00 p.m.	74.5	77	82	67	
24	7:45 a.m.	73	71	—	—	
	8:00 p.m.	78	76	81	68	
26	8:30 a.m.	75.5	75	—	—	
	8:00 p.m.	75.5	78	82	71	
27	10:30 a.m.	74	76	—	—	
	8:00 p.m.	77	78	82	67	
30	7:30 p.m.	72	72	78	70	
31	6:30 p.m.	72	72	71	70	
Aug. 2	9:30 a.m.	73.5	73.5	77	69	
	7:00 p.m.	74	75	79	75	
3	8:00 p.m.	72.5	73.5	79	66	
16	9:00 a.m.	66	67	83	53	
18	5:00 p.m.	64	66	73	53	
28	2:00 p.m.	65	66	78	58	
Sept. 5	9:00 a.m.	67.5	66	79	53	
8	10:00 a.m.	66	63	70	56	
	1:30 p.m.	65	66.5	—	—	
	4:00 p.m.	67	66	—	—	
13	2:00 p.m.	62	60	—	—	Removed fish, 1 cave, 4 river.
Mean		69.2 +	70.1 −	75.3 +	62.9 +	
			69.1 +	(average of all min. and max.)		
Maximum		78	78	83	75	
Minimum		60	60	65	53	

Note. Columns marked "Max. and Min." read on a minimax thermometer at hour noted and reset for next reading.

temperatures were probably below their spawning threshold. In any event there were no young evident, although either eggs or very young fish may have been eaten by the adults or by aquatic insects if such were actually produced.

The experiment was terminated with the advent of cool weather as it was evident that soon their lower threshold would be passed. As it was, some of the minimum temperatures reached and survived by these fish are rather remarkable, especially when it is borne in mind that the home waters of these fish hover about 80° F. Since the fish were variously in and out of the cave it was impossible to keep a close check on the actual numbers present. When the fish were removed on September 13 it was found that only five remained, one blind and four eyed. Less than two weeks previously many more than this number were seen when a warm day drew them out of the cave. It is suspected that with the cooling water and a failure of their alertness that they fell prey to frogs, as the most likely predator normally about these pools. No matter what the cause of their destruction, under the conditions of natural enemies, fluctuating temperatures, et cetera, it is clear that a marked differential of survival is present. Reduced to terms of percentage, 10% of the blind individuals survived while 44+% of the eyed ones were still there when the experiment was terminated. Although it must be admitted that the total numbers are small, those that were recovered were in an excellent state of vigor and are now in aquaria. We have every reason to believe that the difference in numbers has bearing on both the blindness and light color of the cave fish. Incidentally it seemed odd that the frogs did not catch the blind

fish early in the experiment, for although they knew their way around the pool they could not tell where a large frog might be floating and if both were present would sooner or later bungle into the frog's dangling hind legs. At first this unaccustomed accident would cause the frog to give a typical fright reaction but soon the frogs became accustomed to such incidents and on occasion they would turn and act as though to pursue the blind fish. The safety of these fish seemed to reside in the fact that customarily when they do strike into something they ordinarily charge off into another direction at top speed, and then not infrequently seem to be confused and are likely to strike the bottom or something else with which they are fully familiar and take some little time to quiet down again.

Discussion.

Since it has been shown that reactions to temperature gradients override reactions to light in both blind and visual types it may well follow that temperature differentials in a state of nature form an important influence on the entry and further penetration of these caves. There would thus seem to be at least three factors in the behavior of these fish leading to cave entry.

1. Negative phototaxis on the part of blind fish and a tendency for visual types to hide in dark places and peer out.

2. Positive rheotaxis tending to cause these fishes to swim upstream.

3. Positive thermotaxis tending to cause these fishes to move into warmer waters.

The first two requirements of the environment are met by La Cueva Chica and while at the time of our visit the subterranean waters were practically of the same temperatures as surface waters, surely at other seasons the ground waters are warmer than those of surface drainage. During the dry season these ground waters should be cooler than these of the surface if they were not heated from below, a geologic feature of this region with its magnetic layers close to the surface and with an abundance of warm springs.

Although the temperatures encountered in the field were considerably above those obtainable in the pool experiments there is no reason to suppose that the fishes' behavior would be any different in regard to thermal preferences. Incidental to this is the fact shown by Doudoroff (1938) that a variety of marine species will select water warmer than that of their normal habitat, if given the opportunity.

This finding of a temperature gradient reaction helps to account for the presence of fishes as remote from the cave's exit as is evidently possible for them to reach, for presumably there is such a gradient from these cave springs, where they rise from the depths, to the juncture at the river, during part of the year at least, although in the short section of the cave available to human exploration no such gradient was detected. The cave water temperatures taken in a wide variety of places varied scarcely at all from 80° and this quite erratically. In aquaria, the same fish appeared to be not in the least inconvenienced by temperatures in the low ninety degrees although eggs laid in water of such temperatures failed to develop normally. Temperatures as low as 65° and for short intervals dropping to 53° have been survived. It thus appears that these fish have a rather wide temperature tolerance. Nevertheless, normally eyed river fish, hatched in an unfurnished, rectangular and well lighted aquarium with no opportunity to hide at all, voluntarily entered a simulated cave where their eyes were useless, on the stimulation of slight flow or a slight thermal difference. Blind fish of the fifth generation raised in light and without previous experience behaved the same way. Given fishes with three such items in their normal behavior, all that would seem to be necessary, in addition, to establish the observed condition in La Cueva Chica would be a genetic defect involving the eyes and cave factors of the types described.

The differential in survival under the conditions of the experiment may mean but little in terms of the Mexican caves but since the experimental temperatures drew the blind fish out of the cave nearly daily it is tempting to imagine that, had it been possible to reverse conditions at will, a much larger number of blind individuals would have survived.

Summary.

1. Light sensitivity in *Anoptichthys* is lodged in the apparently functionless remnant eye capsule, which may be demonstrated by its removal.

2. Reactions to temperature overrides the influence of light in both the eyed and blind forms and rheotaxis interferes to a lesser extent.

3. Eyed individuals apparently do not attempt to destroy blind ones except under conditions of close confinement.

4. Normal river fish, which never before had an opportunity, entered a simulated cave on temperature differentials of less than 1.5° F. as well as on a slight flow emerging from the darkness.

5. Survival in an outdoor pool divided about equally between light and dark was in favor of the eyed forms slightly better than 4 to 1.

6. Three factors have been experimentally demonstrated as parts of the normal behavior pattern of both eyed and eyeless fishes, which would tend to make them enter caves similar to the one in which found, namely: negative phototaxis, positive rheotaxis and positive thermotaxis.

Bibliography.

Breder, C. M., Jr.

1939. Variations in the nesting habits of *Ameiurus nebulosus* (LeSueur). *Zoologica* 24 (25): 367–378.

1940. The nesting behavior of *Eupomotis gibbosus* (Linnaeus) in a small pool. *Zoologica* 25 (23): 353–360.

Breder, C. M., Jr. & Gresser, E. B.
1941. Correlations between structural eye defects and behavior in the Mexican blind Characin. *Zoologica* 26 (16): 123–131.

Bridges, W.
1940. The blind fish of La Cueva Chica. *Bull. N. Y. Zool. Soc.* 43 (3): 74–97.

Doudoroff, P.
1939. Reactions of marine fishes to temperature gradients. *Biol. Bull.* 75 (3): 494–509.

Gresser, E. B. and Breder, C. M. Jr.
1939. The histology of the eye of the cave characin, *Anoptichthys*. *Zoologica* 25 (10): 113–116.

Shlaifer, A. & Breder, C. M., Jr.
1940. Social and respiratory behavior of small tarpon. *Zoologica* 25 (30): 493–512.

EXPLANATION OF THE PLATE.

Fig. 1. The pool and "cave" as it appeared with the construction work finished but before the placement of soil and planting.

Fig. 2. The pool and "cave" as it appeared shortly after planting. Later the vegetation became considerably more lush, hiding all of the woodwork.

FIG. 1

FIG. 2.

FURTHER STUDIES ON THE LIGHT SENSITIVITY AND BEHAVIOR OF THE MEXICAN BLIND CHARACIN.

29.

Eastern Pacific Expeditions of the New York Zoological Society. XXIX.

On the Growth and Ecology of Brachyuran Crabs of the Genus *Ocypode*.[1]

JOCELYN CRANE

Technical Associate, Department of Tropical Research, New York Zoological Society.

(Plates I–II. Text-figures 1–7.)

[This is the twenty-ninth of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of William Beebe. The present paper is concerned with specimens taken on the Eastern Pacific *Zaca* Expedition (1937–1938). For data on localities and dates of this expedition, refer to *Zoologica*, Vol. XXIII, No. 14, pp. 287–298. Also included in the present paper are results of observations made by the author on the Pacific coast of Panama during January, 1941.]

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I. INTRODUCTION.

The present paper is the third of a series dealing with the brachyuran crabs of the Eastern Pacific *Zaca* Expedition. My sincere thanks go to Mr. Templeton Crocker for the opportunity of making these collections and of studying the crabs in the field, to Dr. William Beebe for his unfailing helpfulness and for leave of absence making possible a special trip to Panama, and to Miss Janet Wilson for her excellent drawings.

The references given under each of the two species discussed include the type description, Rathbun's monograph (1917), and occurrence records which have appeared since the latter date. The collection is deposited in the laboratory of the Department of Tropical Research, New York Zoological Society.

II. SUMMARY OF IMPORTANT POINTS.

1. Young crab stages of *Ocypode gaudichaudii* and *O. occidentalis* differ from adults chiefly in the flatter, more narrow carapace, longer legs, larger eyes, more oblique orbits, smaller chelipeds and different coloration. In *gaudichaudii* the ocular stiles and truncate chelae begin to develop when the crab is less than half grown, the carapace being around 7 mm. in length when the first trace of stiles appears, and 10 mm. when the chelae tips begin to show change in form. In adult males the stile is only slightly longer than in females; this difference is not apparent in young crabs.

2. Adult *gaudichaudii* apparently alone of all the genus feeds habitually on microscopic organic matter in the sand, just as do crabs of the related genus *Uca*. In *gaudichaudii*, however, the technique differs: first, a raking motion of the truncate chelae is substituted for the pinching of sand by the pointed, spooned chelae in *Uca;* second, the specialized endites of the first maxillipeds form sand pellets which drop of their own weight, instead of being wiped off as in *Uca*. Young *gaudichaudii* habitually, and adults rarely, prey on small crustaceans, insects and worms, and sometines add wood and seaweed to

[1] Contribution No. 632, Department of Tropical Research, New York Zoological Society.

Text-figure 1.

Shore collecting stations of the Eastern Pacific Expeditions of the New York Zoological Society.

their diet. *O. occidentalis* is a predator and scavenger.

3. *O. gaudichaudii* is diurnal, *occidentalis* nocturnal except when very young.

4. In contrast to the racing dodging, burrowing adults, the young of *gaudichaudii* run only a short distance when pursued, then flatten themselves in the sand, where protective coloration aids them in escaping observation.

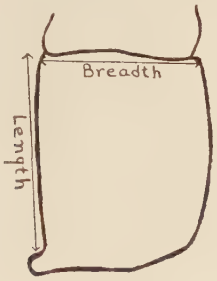
5. Also included in the present paper are descriptions of color in life, stridulation, habitat, burrows and daily schedule, with special emphasis on *gaudichaudii*. Abdominal appendages of the three American species, *gaudichaudii*, *occidentalis* and *albicans*, are illustrated.

III. Key to Immature *Ocypode* from the Eastern Pacific.

O. occidentalis and *O. gaudichaudii*, although so distinct in the adult, are superficially indistinguishable up to a length of about 7 mm., when the ocular stiles and truncate chelae of the latter species begin to develop. However, they may be distinguished when alive by color differences, and when preserved by the proportions of the buccal frame, as shown from the following key. The smallest specimens studied were about 4 mm. in length.

The length of the ischium of the third maxilliped is measured along its external margin in a straight line, as far as but not including the

basal process; the breadth of the ischium is measured across the distal margin. The accompanying diagram illustrates these points.



1a. Living crab with a spot of brilliant scarlet on middle of posterior gastric region, and others on one or more of the meri of the last three pairs of ambulatories. Breadth of ischium of third maxilliped 58 to 69 per cent of its length.....*occidentalis*, p. 308

1b. Living crab without scarlet spots. Breadth of ischium of third maxilliped 77 to 85 per cent of its length.....*gaudichaudii*, p. 209

IV. Crabs of the Genus *Ocypode* Taken by the Eastern Pacific *Zaca* Expedition.

Ocypode gaudichaudii Milne Edwards & Lucas.

Text-figs. 2; 4 A, B, C, D; 5 B, D, F, H; 6 B, D; 7 E, F; Pl. I, Fig. 1; Pl. II, Figs. 3, 4.

References: Ocypoda gaudichaudii Milne Edwards & Lucas, 1843, p. 26; 1847, pl. 11, figs. 4–4b.
Ocypode gaudichaudii, Rathbun, 1917, p. 373; pl. 129, fig. 1; pl. 130, fig. 1; Boone, 1927, p. 267, fig. 96A; 1929, pp. 562, 580; Pesta, 1931, p. 174; Sivertsen, 1934, p. 19; Crane, 1940, p. 67; text-figs. 1–8.

Range: Gulf of Fonseca, El Salvador, to Chile; Galápagos Islands.

Local Distribution: Found on more or less protected beaches and on the shores of lagoons. In one locality (Bahia Honda, Panama), there were more than 3,000 crabs on a beach measuring about 175 × 400 feet. Very rarely found on the same beach with *O. occidentalis*, and then usually one or the other species occurs in the young stages only, so that its presence is doubtless accidental.

Size: The 55 specimes in the present collection measure between 4.8 and 29 mm. in length of carapace. One of Sivertsen's (1934) males from Galápagos was 36 mm. long, and a female 34 mm.

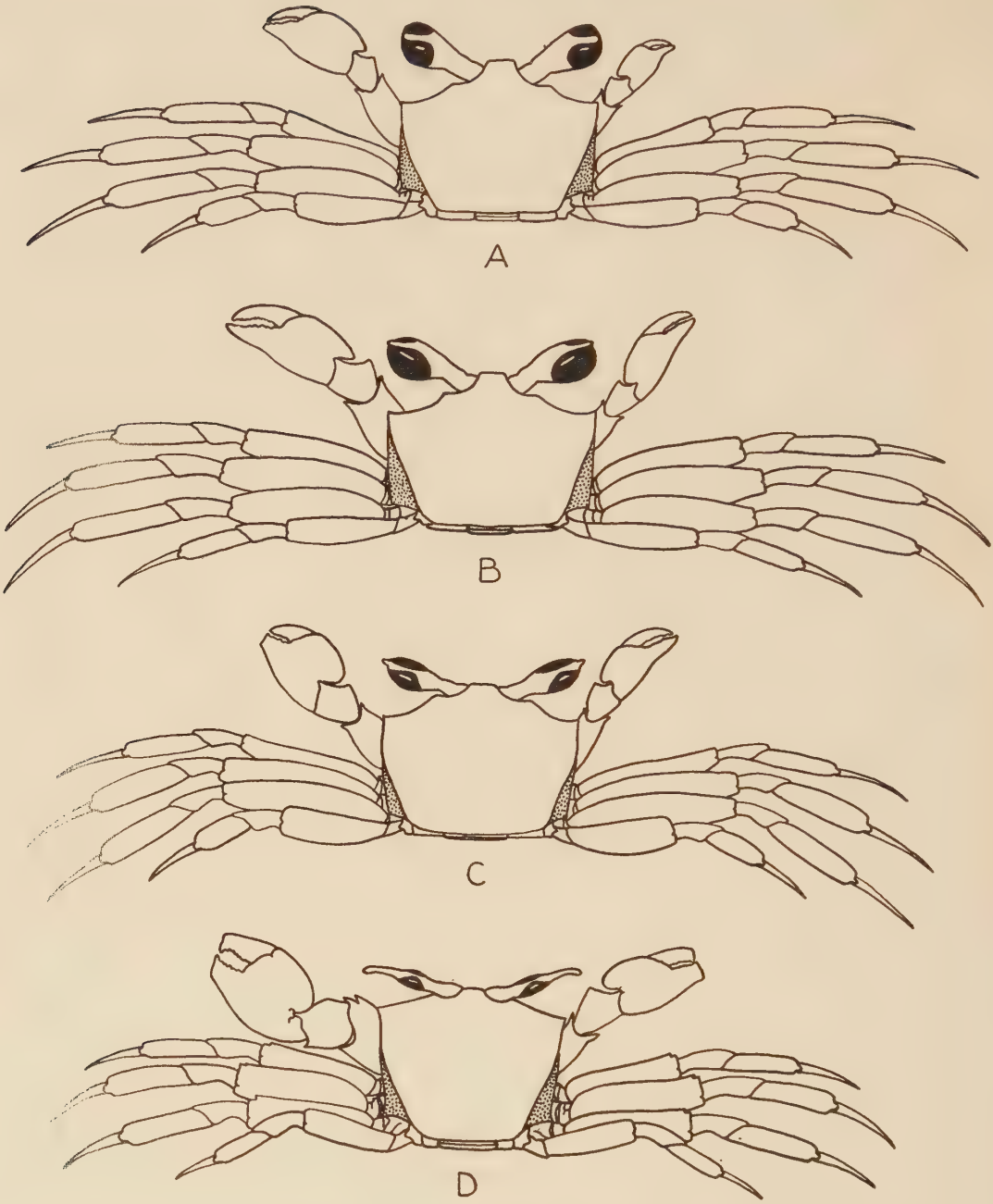
Sexual Characters: Except for the probably larger maximum size and slightly longer ocular stiles of the male, there are no apparent secondary sexual characters. The form of the abdominal appendage in this genus, as in *Uca*, varies among the species, so that it should prove a valuable taxonomic character in the determination of dubious forms. Plate II, Figs. 4, 5 and 6 illustrate the appendages of the three American species.

Color: This species ranges in general color from brilliant coral red to dark brown, marbled or mottled with brown, yellow and yellow-green. The exceedingly variable color is affected by a number of factors, including the color of the sand upon which they live and the sex and size of the individual. No precise observations have yet been made on the influence of light and temperature on the one hand, or of physical and emotional states on the other, but these will undoubtedly prove to be of great importance, and the crab found to be capable of considerable individual variation. The only exact notes taken on the latter subject concerned an ovigerous female: the sides of the carapace were gray-violet when the crab was captured on a dark, stormy day after a long chase over light sand; they changed to moderately bright coral red after two days in a box kept partly in sunshine, its bottom being covered with the same light sand. There was no color change at night. Compare especially the observations of Cowles (1908) on color change in *O. albicans*, Abramowitz & Abramowitz (1940) and Brown (1940) on the effect of eyestalk removal in *Uca*, and Crane (1941) on color change in courting *Uca*. Similar experiments and observations made upon *O. gaudichaudii* should yield interesting results.

In regard to the effect of the environment, it was obvious that crabs on light sand were brightest, with a great deal of orange, carnelian and coral pink, while those on dark, volcanic sand were darkest, with these brilliant colors replaced by browns, rusty oranges and pale pinks. In any group the adult males were brightest, the females paler, the young palest. In specimens less than about 15 mm. long, the parts that were yellow in adults were white, those that were coral or carnelian red were lavender or violet; especially noticeable in the young was a band of violet across the posterior part of the carapace.

Colors of adult males have been noted in detail as follows: ground color of carapace ranging from bright coral or carnelian red in colonies living on the palest yellow sand, through coral pink and rusty orange, to dark brown in colonies on dark slate-colored sand; carapace with mottlings or marblings ranging from pale lemon yellow or chartreuse with dark brown to ochre or chartreuse with cream and white; sides of carapace brilliant clear orange to scarlet orange, sometimes mottled with pink. Eye sockets brilliant orange to dark brown; stalks coral red to pearl gray; eyes pearl gray; stiles scarlet orange to yellow-brown. Merus and carpus of chelipeds orange or orange-brown above with brown mottlings, buffy yellow below and on inner surface; upper third of manus bright coral pink or orange to dark brown; lower two-thirds pinkish-white to lemon yellow; chelae coral pink, orange or lemon yellow. Posterior (dorsal) surface of ambulatories usually like carapace, but dactyls are buff when crab lives on light sand, olive green when on dark sand; anterior (ventral) surface of ambulatories usually pale. Sternum and abdomen bright coral pink, sometimes mottled carnelian red, yellow and white, sometimes fading into white posteriorly.

Early Crab Stages: Several excellent studies on the growth of *Ocypode* have already been pub-



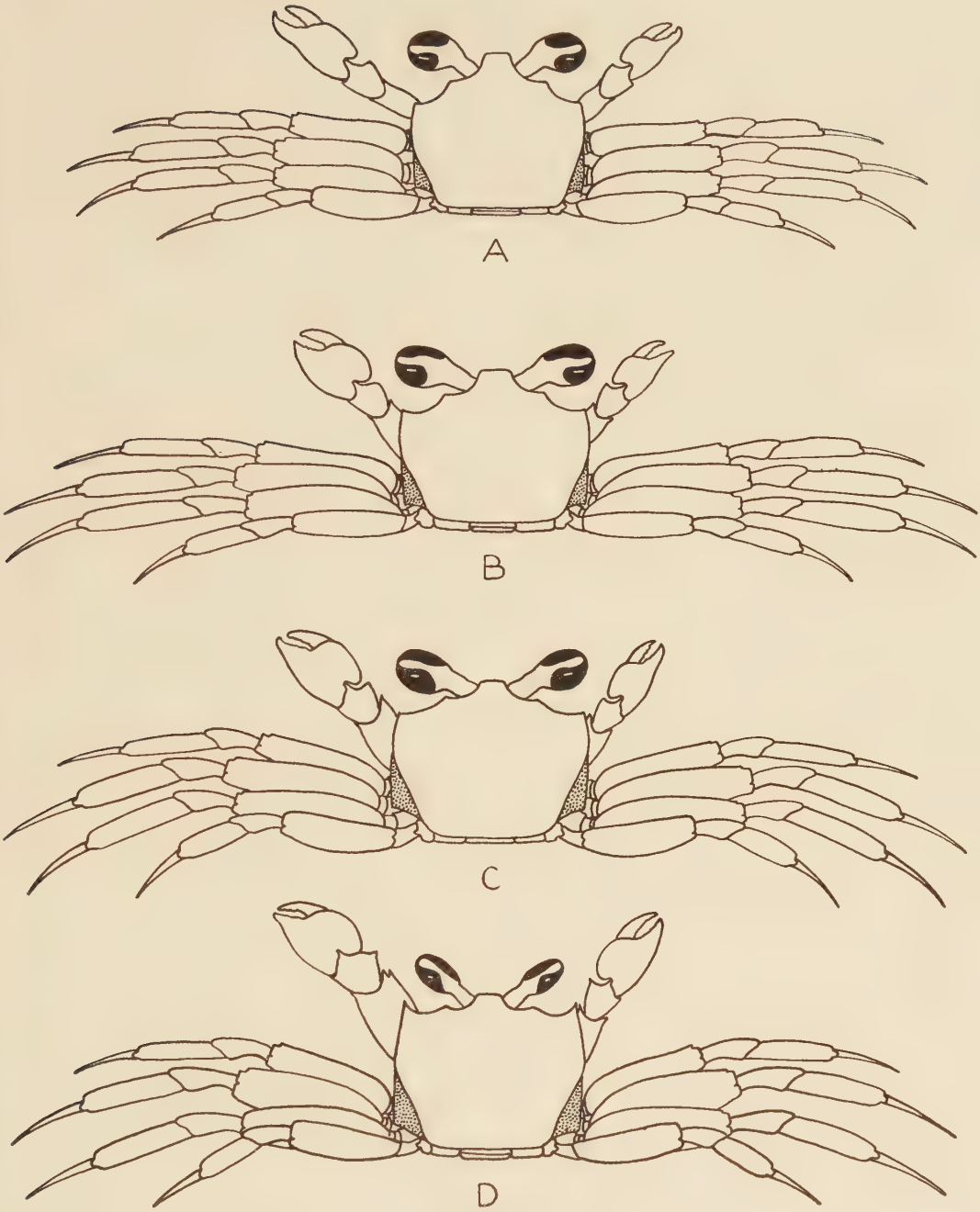
Text-figure 2.

Ocypode gaudichaudii. Growth stages. Carapace lengths: A, 4.8 mm.; B, 7.2 mm.; C, 10 mm.; D, 29 mm.

lished, notably those of Cott (1929), Huxley (1931) and Sandon (1937). It seems worthwhile, however, to summarize and illustrate the changes occurring during growth in *gaudichaudii*, especially since this species is more specialized than others studied (*ceratophthalma* and *aegyptica*).

The changes in *gaudichaudii* were studied from a series of 64 specimens ranging in length from 4.8 to 29 mm., the carapace being measured in the median line. The outstanding growth characters of the young are as follows, all of the observations being of course relative to the size of the crab.

1. The carapace is broader than in the adult,



Text-figure 3.

Ocypode occidentalis. Growth stages. Carapace lengths: A, 4.2 mm.; B, 6.9 mm.; C, 10 mm.; D, 25 mm.

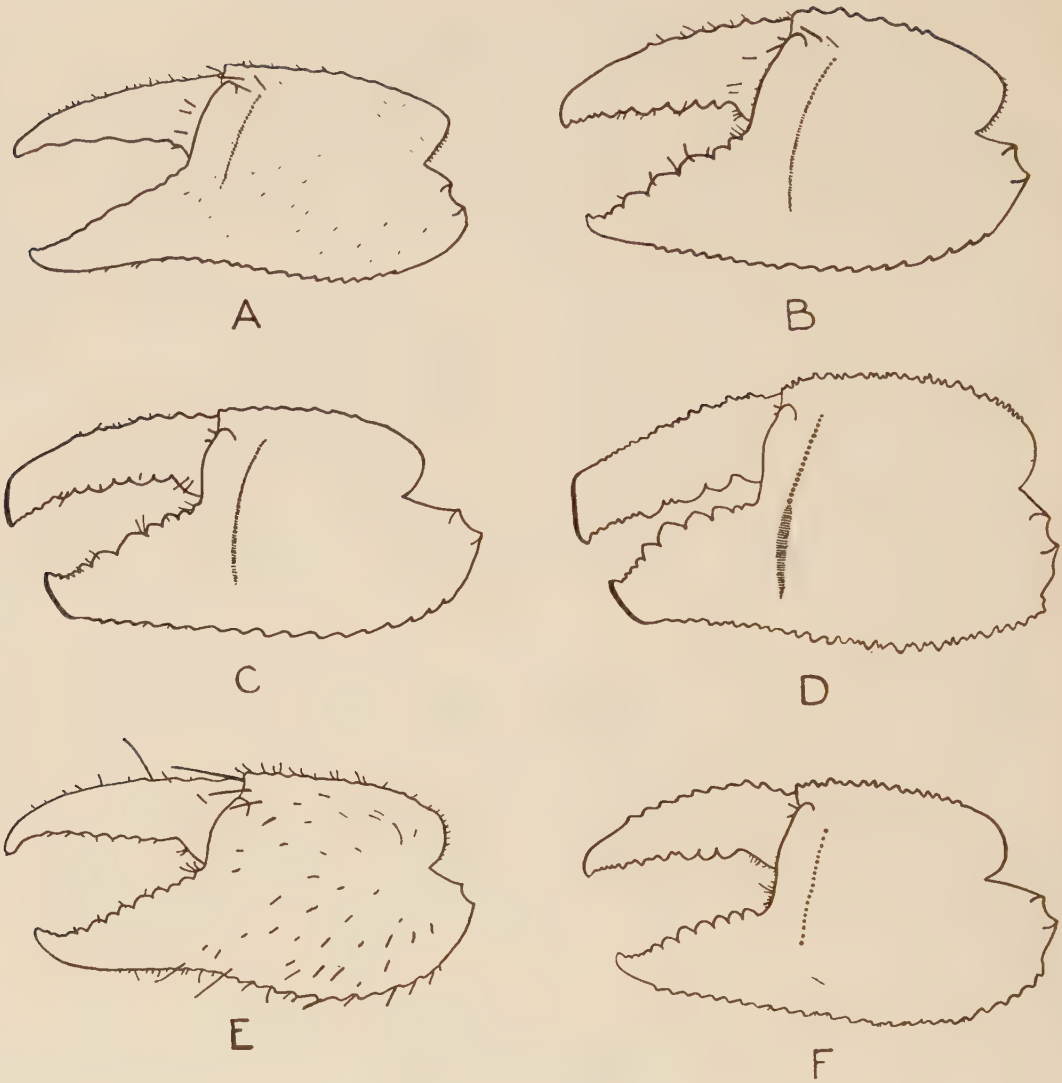
breadth being greatest when the crab is about 7 mm. long.

2. The carapace is less deep.

3. The orbits are more oblique.

4. The eyes are enormous, being broader and thicker as well as longer.

5. The eyestalks are longer and thicker, but there is no trace of stiles until the crab reaches a length of about 7 mm. In their early stages, the stiles are equipped distally with a few hairs, as in adults of certain other *Ocypode*. The stiles will be further discussed below.



Text-figure 4.

Major chelae of *Ocypode*. A to D, incl., *gaudichaudii:* A, female, carapace length 4.8 mm.; B, female, carapace length 7.2 mm.; C, male, carapace length 10 mm.; D, male, carapace length 29 mm. E, F, *occidentalis:* E, female, carapace length 4.2 mm.; F, male, carapace length 25 mm.

6. All the joints of the chelipeds are more slender, the width of the manus being only three-fourths that of the grown crab in a specimen 4.8 mm. long.

7. The chelae show the first signs of truncation when the crab reaches a length of about 10 mm.

8. A stridulating ridge is present even in the smallest (4.8 mm.) crabs, but is composed only of minute, homogeneous granules, instead of having parallel, elevated lines in its upper half. In these smallest examples the inside of the palm is slightly hairy.

9. The ambulatories are relatively longest when the crab is about 7 mm. in length.

10. The colors of the young have already been noted (p. 299).

11. The crabs appear, anatomically, to reach maturity at a length of around 22 to 24 mm.; this point cannot, however, be settled until more is known of their breeding habits. The only ovigerous female taken measured 27.5 mm. in length.

Stiles: A number of writers (for example, Ortmann, 1894, p. 768, Lanchester, 1900, p. 759, and Gordon, 1934, p. 9) have mentioned the fact that in other species of *Ocypode* furnished with ocular stiles the latter are absent in the young and reach their maximum development in large

males. In. *O. ceratophthalma,* stiles do not begin to develop much before a length of 20 mm. is reached (Lanchester, *ibid.*), in contrast to *gaudichaudii,* in which, as has been said, stiles are first visible at a length of about 7 mm. In *gaudichaudii,* too, the sexual difference in stile length is relatively slight, and is not apparent at all until the crab measures about 20 mm. Indeed, in smaller crabs, the stiles on the average are even slightly shorter in males than in females. In both sexes, the stile grows more rapidly after the crab has reached a length of about 20 mm. The following table is based on a series of 31 males and 23 females.

Length of carapace in mm.	*Length of stile in mm.* *Males*	*Females*
4.8 to 6.6	Absent	Absent
7 to 14	0.2 to 1.2	0.1 to 1.0
15 to 19	1.1 to 1.9	1.3 to 2.4
20 to 24	2.4 to 4.3	2.4 to 3.5
25 to 29	4.6 to 7.5	3.2 to 5.5

Largest male, 29 mm. long, stile length 7.5 mm. Largest female, 27.5 mm. long, stile length 5.5 mm.

Dembowski's detailed description (1913) of the glandular organs of the ocular stile and stalk of *ceratophthalma* has apparently not been superceded, while Parenzan (1931) ascribed to the stiles of the same species a tactile and protective function in addition to their glandiferous capacity. It will be interesting to study in detail the functions of both stiles and glands, and to determine whether the latter control chromatophore expansion, as do the sinus glands in the eye-stalks of *Uca* and other crustaceans (see for example Abramowitz & Abramowitz, 1940; Brown, 1939; and Kleinholz & Bourquin, 1941).

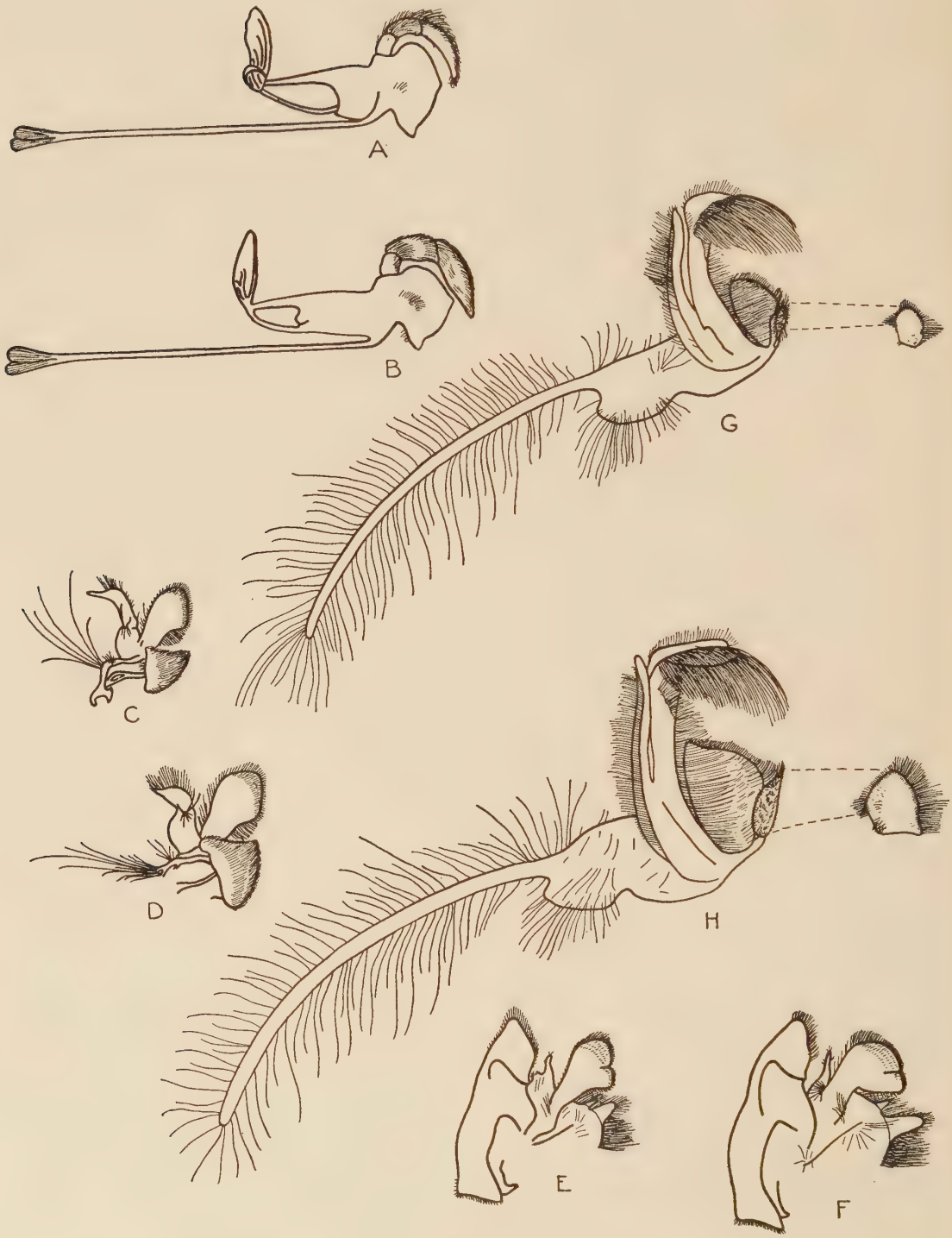
Food, Feeding and Mouthparts: Unlike other members of the genus, which are confirmed predators and scavengers in the usual sense of the word, *gaudichaudii,* except when very young, feeds almost entirely on microscopic organic matter washed onto the sand by the tide, exactly as does *Uca.* As in the latter genus, the minute particles of animal and vegetable matter are gathered by sifting pinches of sand through the mouthparts and dropping the remaining sand in small pellets from the posterior part of the buccal region. In feeding, alternate claws are used, at the rate of four scoops to the second; pellets emerge at two to the second. Rejected pellets of large crabs measure on the average one-quarter to three-eighths of an inch in length and are broadly oval.

The details of the method by which the food is gathered, although analogous to the procedure in *Uca,* are in *O. gaudichaudii* unique. In *Uca* the minor chelae are spooned, and literally pinch up clawsful of sand, the dactyl being widely extended before every pinch. In *O. gaudichaudii,* the sand is not picked up between the chelae, but instead the latter are held almost closed, and used simply as broad-toothed rakes, scraping backward, inward and upward. The inner surfaces of both dactyl and pollex are slightly concave, and this characteristic, combined with their truncate tips, must make them almost or quite as efficient sand-gatherers as the entirely different chelae of *Uca.* Each scoop of sand, as in *Uca,* is swiftly lifted to the anterior end of the buccal cavity, where it is swept from the chelae by the palps of the third maxillipeds. No way has yet been found of watching exactly how the organic matter is separated inside the mouth, although as in similar observations on *Uca* the parts can be seen to be in rapid motion.

Whatever the details of manipulation in *gaudichaudii,* it is apparent that the sand about to be rejected is formed into a pellet in the middle of the lowest (most posterior) part of the buccal cavity, between the enlarged endites of the first maxillipeds. The pellet is not wiped off by the chelae, as in *Uca,* nor does the sand simply accumulate outside haphazardly and drop by means of gravity; instead, it appears to be carefully moulded into a pellet, by the up-and-down motion of the endites, and dropped. Since damp sand lacks much of the stickiness of mud, such a procedure is practicable in this crab, whereas it would be impossible in most *Uca,* which are largely mud-feeders (cf. Crane, 1941). The technique of separation is not perfect, since small amounts of sand are usually found mixed with the organic matter in the alimentary canal.

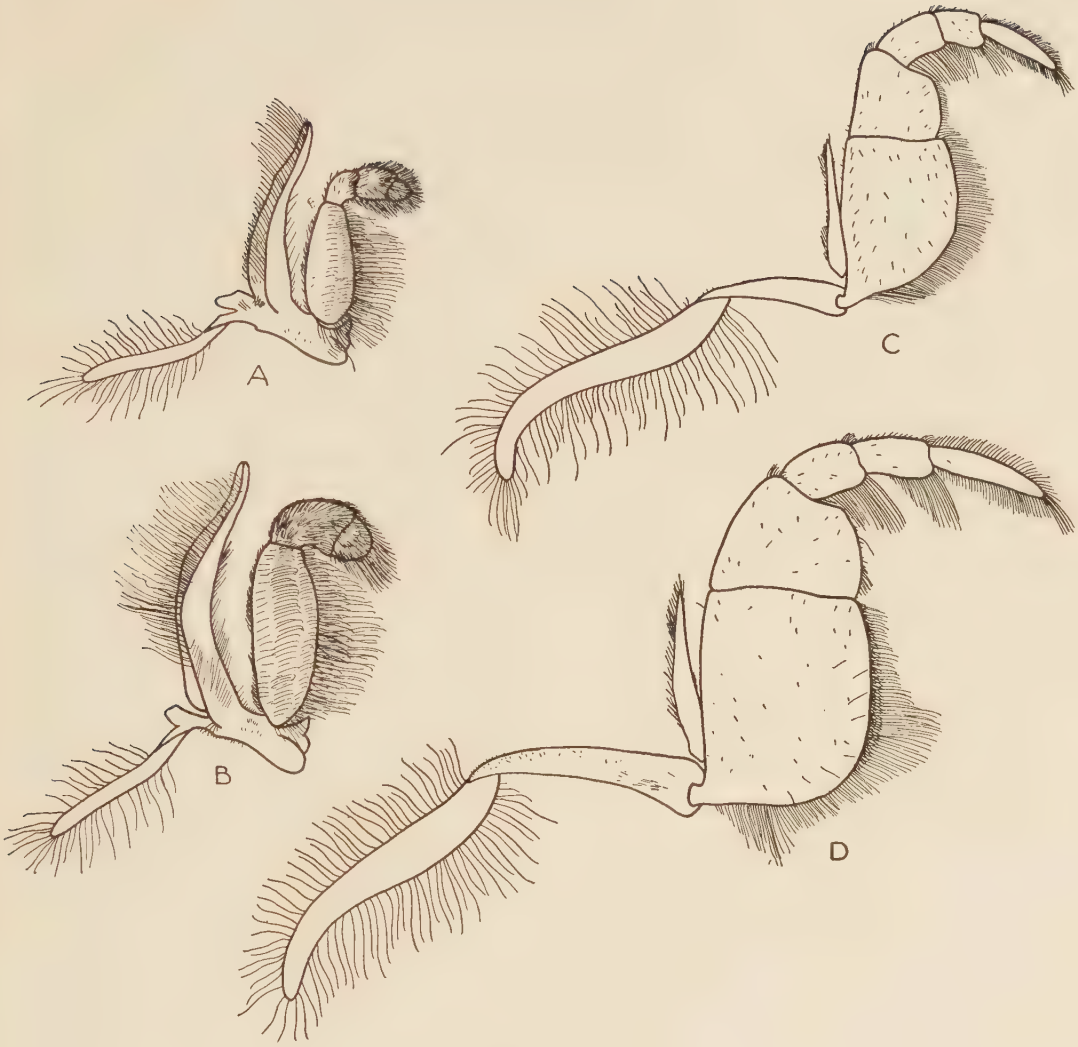
A comparison of the mouthparts of *gaudichaudii* with those of *occidentalis* is enlightening. The latter in feeding habits is a typical *Ocypode,* the west coast analogue of *albicans,* and feeds on the usual assortment of seaweed, carrion, amphipods, insects, etc. I have never seen it put sand into its mouth, and have rarely found grains in its stomach.

In *gaudichaudii,* the entire mouth field is much larger than in *occidentalis,* ranging from 25 to 30 per cent. more in both length and width, and with the parts correspondingly larger, a condition which is apparently useful in manipulating large quantities of sand. In *gaudichaudii,* too, the hairs on the mouthparts are much longer and thicker, although not as long as in mud-living *Uca*'s, where even more straining work is necessary than in sand-living *Ocypode.* Specifically, the hairs on the inner margins of the third maxillipeds are up to more than three times as long, and those on the second maxilliped one and a half times to twice as long. The maxillae are also larger and tougher and the mandibles slightly longer. There are no pectinated spoon-tipped hairs, so characteristic of most fiddler crabs, on the second maxilliped of either species of *Ocypode;* in both, however, there is a row of short, thickened hairs on the inner (dorsal) side of the merus and a cluster of similarly thickened and slightly concave hairs among the normal ones on the tip of the palp; these stout hairs are slightly longer and more numerous in *gaudichaudii* than in *occidentalis.* The anterior margin of the sternum is broader in *gaudichaudii,* squared off and slightly concave, perhaps for better retention of the sand during manipulation, while



Text-figure 5.

Mouthparts of *Ocypode*. A, mandible, *occidentalis;* B, same, *gaudichaudii;* C, first maxilla, *occidentalis;* D, same, *gaudichaudii;* E, second maxilla, *occidentalis;* F, same, *gaudichaudii;* G, first maxilliped, *occidentalis;* H, same, *gaudichaudii*. All × 4.1, from ♂'s 25 mm. long.



Text-figure 6.

Mouthparts of *Ocypode*. A, second maxilliped, *occidentalis;* B, same, *gaudichaudii;* C, third maxilliped, *occidentalis;* D, same, *gaudichaudii*. All × 4.1, from ♂'s 25 mm. long.

in *occidentalis* this area is narrower, sloping and convex.

The most interesting of the differences, however, lies in the development of the proximal endites (basipodites) of the first maxillipeds. In *Ocypode* as in *Uca* there is considerable space between the anterior tip of the sternum, which extends upward between the maxillipeds, and the mandibles. In *gaudichaudii*, however, there is twice as much as in *occidentalis*, in which the extra space is negligible. In *gaudichaudii* this extra space is occupied chiefly by the proximal endites of the first maxillipeds—which, instead of lying almost useless on each side of the sternal projection, with their flat sides turned backward against the sternum (as in grapsids, portunids, etc.), are in *gaudichaudii* and *Uca* enlarged, thickened, and their flat surfaces closely opposed to each other, exactly like a pair of butter-ball paddles. The distal endites (coxopodites) and the maxillae, in normal position, thus support and strengthen them laterally, instead of being anterior to them. In *occidentalis* the general form and position of the proximal endites are almost the same, but they are so small and weak, and there is so little space for them that they obviously could not function as paddles.

An examination of a series of alimentary tracts combined with observation in the field, showed first, that feeding habits changed with growth and, second, that large crabs occasionally varied their planktonic diet with other items. Twenty-one stomachs and intestines were examined, from crabs measuring between 5 and 29 mm. in length, taken in eight different localities. This series divided itself naturally into two parts,

one including crabs less than 9 mm. in length, and the other of those longer. The seven alimentary canals comprising the first group contained no trace of sand, and the contents consisted entirely of amphipods and tiny insects, including beetles, in an easily recognizable state. Obviously at this stage, in which the chelae have not become truncate, the crabs are chiefly predators—just as they were in the megalopal stage—and, doubtless, scavengers as well. Similarly, their food is identical with that of other *Ocypode* from the young of which, physically, they are scarcely to be distinguished.

After a length of 9 or 10 mm. has been attained, however, the crabs commence feeding almost entirely by means of sifting plankton from the sand. Correlated with this is a concomitant development of the truncate chelae. As was to be expected, the stomach contents of this second group, numbering 14 crabs, consisted of particles of organic detritus, including diatoms and minute algae. Ten stomachs included more or less sand in addition. In only four was nonplanktonic matter found, and in these sand was present in the intestine, showing that the unusual food was not habitual: the stomachs of two adults from the same locality held isopods and bits of wood; another had worm spicules and pieces of seaweed; and a fourth held a small crab, probably *Sesarma*. These must be regarded as exceptional; several times I have seen large colonies of *gaudichaudii* scooping up the sand, while a dead fish or bird lay untouched in their midst, although hermit crabs busily feeding on the carcass attested its worth as food to true scavengers.

I have never seen a member of this species behave as reported to Miss Rathbun (1917, p. 374) by Tristan, although I have baited them with a number of objects, edible and inedible, including both animal matter and seaweed: "If anything falls near them," wrote Tristan, "they jump at it with extraordinary rapidity, as a spider in its web, and try to secure it with their claws so as to carry it off quickly to their holes." Similarly, I have never found material of any kind in their holes.

The only mention I find of other *Ocypode* feeding in the manner of *gaudichaudii* is that of Takahasi (1935), who reports that the *young* of *ceratophthalma* and *cordimana* feed on plankton and make "sand-balls," along with *Uca*, *Scopimera*, *Ilyoplax* and *Mictyris*. It is interesting that the young of *gaudichaudii* are, in contrast, predators.

Burrows: The burrows are of three main types, and I have not been able to discover that each type is the work of a certain size or sex, or dug in a given sort of locality. The most usual form made by adults seems to be a burrow which goes 6 to 12 inches straight down, then turns at a right angle or more and continues for an almost equal distance. Other individuals, however, dig straight down for six inches, and then continue in a slow spiral. Still others dig a simple, oblique burrow about nine inches long, ending about six inches underground. To discover which, if any, is the normal type, plaster casts must be taken in a number of localities.

The method of digging agrees in general with the method used by other *Ocypode*, the sand brought up being carried by the first and second ambulatories on the side of the minor cheliped (the side which usually enters the hole first and leaves last). The minor cheliped is laid flat against the load of sand, bearing no weight, but holding it in place. Small loads may be taken two or three feet from the hole and flicked six inches still farther, being flung sideways and forward through the legs and under the cheliped of the other side. Large loads, however, which in large crabs are the usual kind, are simply dumped close to the hole.

In Panama City I noticed a habit which had not been apparent in crabs farther north. When the load has been released near the hole, the crabs deliberately stamp the sand flat with the outer sides of the palm of the chelipeds rapping alternately and quickly against the ground. Simultaneously similar motions are made by the dactyls of the first two pairs of ambulatories, which, instead of bearing the weight of the crab on their tips in the usual fashion, are turned inward, so that the weight rests on the dactyls' entire length, and more pounding surface is given. By just a few of the patting motions the heap of sand becomes almost indistinguishable from its surroundings; on the way back to the hole after an absence the crab usually continues the process, apparently to take care of any stray slippings. Also, they frequently stamp in the immediate vicinity of the hole even when they have not brought up a load.

The procedure was exactly similar to that observed in male *Uca* in preparing a smooth display ground, free from pellets and digging lumps alike, in front of its burrow. All the instances were seen on rather dry sand in January. No evidence of courting activity was seen, although it may be that this action is connected with it. It was not seen in equally detailed observation of the species at Bahia Honda, in northern Panama, in March. It may, of course, be connected only with the type of sand, but it is worth noting that it may prove to be a definite part of courtship. Among these stamping crabs a number of rudimentary fights were seen; chelae were never locked as in *Uca*, but were used only in very brief sparring matches.

In one instance, a large crab, the sex of which was not determined, stamped down a fresh load carefully, then darted eighteen inches away to the newly started hole of a smaller crab. The latter had brought up three or four loads and dumped them in as many different places, without stamping them down at all. The first crab stamped down one of the second crab's loads, then chased the animal several feet, watched it keep on running, then returned to the newly started hole and deliberately kicked sand into it

until it was almost indistinguishable from the surrounding beach. The aggressor then returned to its own hole and resumed repair work.

Defense: Crabs of this species employ four distinct types of defense mechanism, according to their size. The smallest noticed, measuring less than 8 mm. in length, are perfectly matched to the sand in color, being finely and evenly marbled with buff and black on carapace and legs. They take every advantage of the similarity in color, since they run only a few feet, or dodge a few inches, when pursued, then flatten themselves and remain motionless on the open sand. These smallest crabs were not seen to escape down holes, even when they were at hand, and apparently had none of their own; the smallest crabs found digging burrows measured between 7 and 8 mm. in length.

If a moderate-sized crab—that is, one too small to have any orange developed dorsally—is dug up and, its hole having been destroyed, allowed to escape, it will, if pursued with moderate force, try to take refuge in a footprint or any other kind of depression in the sand, where it flattens itself and blends in color exceedingly well. However, if still pursued, it will descend any available hole.

Large crabs when pursued never depend on flattening in a depression to escape notice, which would, of course, be impossible thanks to their usually striking color, Instead. they run swiftly, in typical *Ocypode* fashion, to their own hole if possible, or, if not, to that of any neighbor; if this is impossible they dodge and double on the open sand, or seek the shelter of nearby rocks. None of this species, of any size, was seen to take to the water except for a single ovigerous female, which was apparently aërating her eggs.

Large crabs at bay employ the fourth means of defense, which, of course, is the assumption of a threatening attitude, with the nippers upraised and open, as the crab makes every attempt to pinch the attacker.

Stridulation: Alcock's (1892, p. 336) and Anderson's (1894, p. 138) observations on the use of stridulation apply equally well to this species. Whatever its other uses, if any, it certainly is a means of warning trespassers that a burrow is occupied. More than a dozen crabs of both sexes were dropped into the holes of as many others. In each case, when the ear was bent over the hole, distinct twittering squeaks were heard, especially at first. However, if I remained in position, apparently giving evidence of my presence through the shading of the hole, the two crabs always seemed to come to some sort of compromise in regard to sanctuary, the squeaking ceased, and the trespasser remained down the strange hole indefinitely. Naturally, strange large males caused the most commotion. The usual result, as found by subsequent digging, is for the newcomer hastily to dig itself a little niche in the side of the tunnel, the displaced sand forming a loose plug in the mouth. The scrape of the bodies against each other and the digging sounds can be heard, quite distinct from the stridulation. Although the latter may be imitated artificially with a crab held in the hand, it is higher pitched when performed naturally in a burrow. Presumably only the rightful owner stridulates, but this point has not been checked, as it could perhaps be in a glass-sided terrarium. If the observer retires promptly to a distance of about twelve feet, the trespasser will emerge within two minutes, and pause at the mouth for several minutes more until certain that the danger is past.

Miss Rathbun (1917, p. 374) quoted a note from Tristan regarding this species as follows: " . . . at low tide the crabs begin to come out sideways, remaining on the edge of the holes and hiding very quickly at the slightest noise." Although they are extremely sensitive to movement, my own observation and experiments indicate that noises (excluding, of course, their own stridulation) have absolutely no effect on them.

Daily Schedule: The following notes are based chiefly upon observations at Bahia Honda, Panama, on a large colony living on light sand. The beach is close to the mouth of the bay, but protected from the full strength of the surf by an island close to shore. The holes as usual were all in the upper third of the beach, and covered at high tide.

These crabs are decidedly diurnal, and their daily routine is similar whatever their habitat. An individual, upon emergence from his hole near high tide line as the water recedes, is apparently very tired, and sits beside its hole, obviously resting, leaning first on one side, then on the other. At the slightest disturbance, even the close approach of a neighboring crab, it will reenter its hole. However, hermit crabs sometimes come up and touch a recently emerged *Ocypode* without the latter's paying the slightest attention. After some minutes' rest, during which some of the clinging sand has dried and fallen off, the crab cleans itself thoroughly, beginning with the polishing of the eyes with the palp of the third maxilliped. Not until almost an hour has passed do the largest crabs start toward the edge of the tide to feed. At first they walk slowly, then more rapidly, and at last gain their usual racing gait.

Feeding is carried on just in advance of the tide for an hour or more. Then the crabs return to the upper beach. (It is not yet certain that they return to the same holes they occupied during the preceding high water.) In any case each crab finds itself a burrow, which it repairs or enlarges according to its needs, or, rarely, it digs a new one. This work is punctuated with periods of feeding close to the hole. Sometimes there is still time after burrow repairs to feed at a distance again. Then the crabs gradually retire to their burrows, usually pulling in a plug of sand after them, until, fifty minutes to an hour before high tide, not a crab is left on the beach.

An interesting relationship was noted at Honda between the crabs and a nocturnal hermit

crab, not yet identified. This crustacean often was seen to come down from the jungle and enter the recently vacated hole of a beach crab, pull in a plug of sand, and spend the rest of the day, including, apparently, the succeeding high tide, if darkness did not fall before. *Ocypode* returning from the lower beach to find holes were never seen to pay the least attention to these newly occupied burrows, and no crabs appeared to be lost, or searching, in their vicinity. It may be that *Ocypode,* on broad beaches such as this, where they feed far from their holes, do not have a sense of property in regard to their burrows, once they have abandoned them after high tide, whereas crabs on narrow beaches, never straying far, may inhabit the same holes day after day.

O. gaudichaudii, as has been said, is active only during the day. In Panama City, on two nights, one brilliantly moonlit and the other dark, visits were made to the quite deserted beach where these crabs were numerous during the day. Although the holes had been opened by the crabs since the high tide (which fell after dark in each case), still not a crab had been feeding, as shown by the complete absence of pellets. The crabs themselves were usually found to be near the top of their sloping burrows, apparently asleep, since they were dug out without difficulty, whereas in daylight they always had to be dug from the very bottom of the long burrow.

The following is a typical time table of their daily activities, worked out from several days' observations on the broad beach at Bahia Honda. Sporadic observations made elsewhere agreed with these.

Hours After High Tide	
½	First young crabs emerge. (Since holes are not deep, tide leaves them first.)
1	First large crab emerges.
2	First large crab goes down to water's edge.
2–6	Migration of crabs to water's edge; the largest last, since they have deepest holes.
Hours Before High Tide	
3–1	Most crabs redigging holes and feeding intermittently around holes and at water's edge.
1	Last crab in hole. Largest are last to descend.

Obviously, this program can be carried out without postponement, interruption or curtailment due to darkness only when high tide is in the early morning or late afternoon. At Panama City, where there are exceptionally high tides, some members of a colony inhabited burrows which were not covered by neap tides. These individuals apparently spent most of their time quiescent in their holes during these periodic "droughts." More study is needed on this subject.

Material: In addition to the zoeae and megalopa recorded in a previous paper (Crane, 1940,[2] pp. 67, 70), a total of 55 specimens of *O. gaudichaudii* was taken by the Eastern Pacific *Zaca* Expedition in the following localities: Meanguera I., Gulf of Fonseca, El Salvador (Cat. No. 37,677); Corinto (37,736) and San Juan del Sur (3838), Nicaragua; Port Parker (3857), Port Culebra (38,141), Piedra Blanca Bay (38,198), Uvita Bay (38,442), Golfito (38,529) and Parida Island (38,651), Costa Rica; Bahia Honda (38,682), Panama; Gorgona Island (38,838), Colombia. In addition, 11 specimens were taken in Panama City, Panama, in February, 1941 (Cat. No. 4150).

Ocypode occidentalis Stimpson.

Text-figs. 3; 4 E, F; 5 A, C, E, G; 6 A, C; 7 A, B; Pl. II, Fig. 5.

References: Ocypoda occidentalis Stimpson, 1862, p. 229. *Ocypode occidentalis,* Rathbun, 1917, p. 372, pl. 129, figs. 2, 3; Rathbun, 1923, p. 632; Boone, 1929, pp. 562, 580, fig. 16; Crane, 1940, p. 70, text-figs. 3–8.

Range: Turtle Bay, west coast of Lower California, to Peru.

Local Distribution: Almost always found on unprotected beaches which are beaten by heavy surf. Occurs rarely on outer beaches somewhat protected by mud flats.

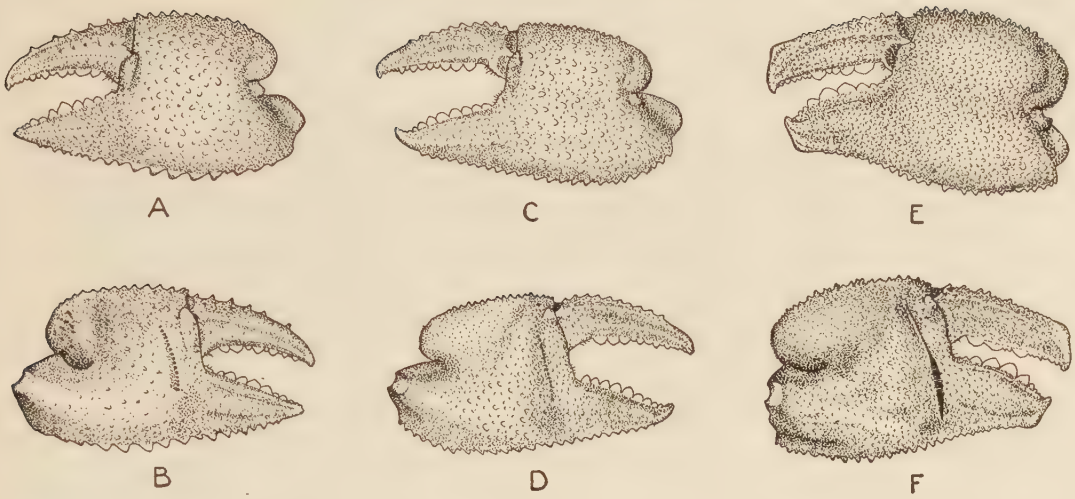
Size: The 35 specimens in the present collection measure between 3.9 and 24.5 mm. in length of carapace. The male co-type measured 43.2 mm. long.

Color: This species is much less highly colored than *gaudichaudii,* being always very pale, and always found on light sand. The carapace and legs of adults show marblings of gray and white on olive; the joint between merus and carpus of chelipeds is darkest, usually brownish; manus of chelipeds, all dactyls and underparts white.

The young are much more boldly patterned, with dark brownish-gray or even black marblings and splotches on olive buff. Legs banded irregularly with dark brown and gray. In the smallest there is a spot of scarlet in the middle of the posterior gastric region, and another on the merus of the last three pairs of ambulatories. In specimens of around 10 mm. in length, the red spots remain only on the gastric region and the most posterior ambulatory. In large crabs, measuring around 20 mm. or more, no trace of scarlet is found.

Early Crab Stages: Excluding the remarks concerning the specialized ocular stiles and chelae, the account of the young stages of *gaudichaudii* (p. 299 ff.) applies equally well to the present species, except that the stridulating ridge is not discernible in *occidentalis* until a length of about 6 mm. is reached. As shown in the key (p. 299), the young of the two forms may be distinguished

[2] In this paper reference was inadvertently omitted to Kemp's (1915) quotation of Annandale's notes concerning the behavior of the megalopa of *O. macrocera.* Dr. Annandale found that they made rudimentary burrows under the shelter of beached catamarans, became pale in strong light, and that they were preyed upon by adult crabs and, apparently, by ants. (Kemp, "Fauna of the Chelka Lake. Crustacea Decapoda." *Mem. Ind. Mus. Calcutta* 5, 1915, pp. 219–220, text-fig.)



Text-figure 7.

Major chelae of adult males in *Ocypode*. A, *occidentalis*, outer side; B, same, inner side; C, *albicans*, outer side; D, same, inner side; E, *guadichaudii*, outer side; F, same, inner side. All × 1.6.

by their coloration when alive and, when preserved, by the proportions of the ischium of the third maxilliped. From a phylogenetic point of view, it is interesting that in young *occidentalis* the orbital angles are even less advanced than in adults of the Atlantic species, *albicans*, although in adult *occidentalis* the reverse is true. Specimens measuring around 20 mm. in length appear to be mature. None of the few large specimens in the present collection seems to be near breeding condition.

General Habits: This species is clearly the analogue of the Atlantic *albicans*, and their habits turn out to be very similar, while utterly dissimilar to those of *gaudichaudii*. Like the Atlantic form, the present species is wholly nocturnal when adult, although the young are also active during the day. They are typical predators and scavengers at all ages.

The alimentary canals of twelve specimens were examined, from crabs measuring between 6 and 25 mm. in length, taken in eight different localities. The contents were distributed as follows: Amphipods were present in four specimens, beetles in four, seaweed in three, worms (setae and jaws) in two, Thysanura in two, a minute sea urchin in one, and one was empty. In four a few sand grains were mixed with the organic matter.

Material: In addition to the megalopa recorded in a previous paper (Crane, 1940, p. 70), a total of 35 specimens of *O. occidentalis* was taken by the Eastern Pacific *Zaca* Expedition in the following localities: Banderas Bay (Cat. No. 37,132), Chamela Bay (37,165), Tenacatita Bay (37,199), Acapulco (37,278), and Port Guatulco (37,445), Mexico; Gulf of Fonseca near Potosi River (37,702) and Corinto, Nicaragua; Port Culebra (38,125), Costa Rica; Bahia Honda (38,698), Panama.

V. Bibliography.

Abramowitz, R. K., & A. A. Abramowitz.

1940. Moulting, growth and survival after eyestalk removal in *Uca pugilator*. *Biol. Bull.*, Vol. 78 (2): 179–188. 1 fig.

Alcock, A.

1892. On the stridulating apparatus of the red *Ocypode* crab. *Ann. Mag. Nat. Hist.* (6), Vol. X, p. 336.

Anderson, A. R.

1894. Note on the sound produced by the ocypod crab (*Ocypoda ceratophthalma*). *Jour. Asiat. Soc. Bengal*, Vol. LXVIII, pp. 138–9.

Beebe, W.

1938. Eastern Pacific Expeditions of the New York Zoological Society, XIV. Introduction, Itinerary, list of stations, nets and dredges of the Eastern Pacific *Zaca* Expedition, 1937–1938. *Zoologica*, Vol. XXIII, pp. 287–298.

Boone, L.

1927. The littoral crustacean fauna of the Galapagos Islands. Part I. Brachyura. *Zoologica* 8 (4): 127–288. 1 pl., 69 fig.

1929. A collection of Brachyuran Crustacea from the Bay of Panama and the fresh waters of the Canal Zone. *Bull. Amer. Mus. Nat. Hist.* 58 (11): 561–583. 18 fig.

Brown, F. A., Jr.

1939. The source of chromatophorotropic hormones in crustacean eyestalks. *Biol. Bull.*, Vol. 77 (2), p. 329.

1940. The crustacean sinus gland and chromatophore activation. *Physiol. Zool.*, Vol. XIII, pp. 343–355. 1 fig.

Cott, H. B.

1929. The Zoological Society's expedition to the Zambesi, 1927: No. 3. Observations on the natural history of the racing crab *Ocypoda ceratophthalma* from Beira. *Proc. Zool. Soc. London* 1929 (4), pp. 755–765.

Cowles, R. P.

1908. Habits, reactions and associations in *Ocypoda arenaria. Papers from the Tortugas Laboratory of the Carnegie Inst. Wash.* II, pp. 3–39, 4 pls., 10 text-fig.

Crane, J.

1939. The Painted Ghosts of Honda Bay. *Bull. N. Y. Zool. Soc.*, Vol. XLII, pp. 19–25.

1940. Eastern Pacific Expeditions of the New York Zoological Society, XVIII. On the post-embryonic development of brachyuran crabs of the genus *Ocypode. Zoologica*, Vol. XXV, pp. 65–82; text-figs. 1–8.

1941. Eastern Pacific Expeditions of the New York Zoological Society, XXVI. Brachyuran crabs of the genus *Uca* from the west coast of America. *Zoologica*, Vol. XXVI, pp. 145–208; text-figs. 1–8; pls. I–IX.

Dembowski, J.

1913. Uber den bau der augen von *Ocypoda ceratophthalma* Fabr. *Zool. Jahrb. Jena Abt. fur Anat.* Vol. XXXVI, pp. 513–524; 1 pl.

Gordon, I.

1934. Crustacea Brachyura. *Res. Sci. du Voyage aux Indes Orientales Neerlandaises de 11. AA. RR. le Prince et Princesse Leopold de Belgique.* Vol. III, Fasc. 15, pp. 1–78. 37 figs.

Huxley, J. S.

1931. Notes on differential growth. *Amer. Naturalist* 65 (699); pp. 289–315. 7 fig.

Kleinholz, L. H., & Bourquin.

1941. Effects of eye-stalk removal on decapod crustaceans. *Proc. Nat. Acad. Sci.* Vol. XXVII, pp. 145–149.

Lanchester, W. F.

1900. On a collection of crustaceans made at Singapore and Malacca. Part I, Crustacea Brachyura. *Proc. Zool. Soc. London.* 1900, pp. 719–770, pls. xliv–xlvii.

Milne Edwards, H., & Lucas, H.

1843. Crustacea. *D'Orbigny's Voyage dans l'Amer. Merid.*, Vol. VI.

1847. Atlas. *D'Orbigny's Voyage dans l'Amer. Merid.*, Vol. IX.

Ortmann, A. E.

1894. Die Decapoden-Krebse der Strassburger Museums. *Zool. Jahrb., Jena, 2 Abt. fur Syst.* VII, pp. 683–772; pl. XXIII.

Parenzan, P.

1931. Osservazioni biologische sull' *Ocypoda ceratophthalma Fabr. Atti R. Ist. Veneto Sci. Lett. ed Arti* 90 (9/10); pp. 1001–1008. 3 pl. 1930 (1931).

Pesta, O.

1931. Ergebnisse der Osterreichischen Biologischen Costa-Rica-Expedition 1930. I. Teil. Crustacea Decapoda aus Costa-Rica. *Ann. Naturhist. Mus. Wien* 45, pp. 173–181. 2 pl., 1 fig. 1931.

Rathbun, M. J.

1917. The grapsoid crabs of America. *Bull. U. S. Nat. Mus.*, No. 97.

1923. The brachyuran crabs collected by the U. S. Fisheries Steamer *Albatross* in 1911; chiefly on the west coast of Mexico. *Bull. Amer. Mus. Nat. Hist.*, N. Y., Vol. 48, pp. 619–637; 9 pls.

Sandon, H.

1937. Differential growth on the crab *Ocypoda. Proc. Zool. Soc. London*, 1937, pp. 397–414; 4 figs.

Sivertsen, E.

1934. Littoral crustacea decapoda from the Galapagos Islands (1933). (Norwegian Zool. Exped. to the Galapagos Is. 1925. VII.) *Nyt. Mag. Naturvidensk.* 74: 1–23. 4 pl., 1 fig. 1934.

Stimpson, W.

1862. Notes on North American Crustacea in the Museum of the Smithsonian Institution. No. 2. *Ann. Lyc. Nat. Hist. N. Y.*, Vol. VII, pp. 176–246; 2 pls.; 1860 (1862)

Takahasi, S.

1935. Ecological notes on the ocypodian crabs (Ocypodidae) in Formosa, Japan. *Annot. Zool. Jap.*, Vol. XV, pp. 78–87; 1 pl.; 1 text-fig.

EXPLANATION OF THE PLATES.

Plate I.

Fig. 1. *O. gaudichaudii.* Buccal frame of adult female, carapace length 25 mm. E marks enlarged endite of first maxilliped. Bahia Honda, Panama. × 3.5.

Fig. 2. *O. occidentalis.* Buccal frame of adult female, carapace length 24.5 mm. Port Guatulco, Mexico. × 3.5.

Plate II.

Fig. 3. *O. gaudichaudii* beside burrow, with heap of excavated sand, feeding pellets and scraping marks of truncate chelae. Bahia Honda, Panama.

Fig. 4. *O. gaudichaudii.* Right abdominal appendage, right lateral view. Carapace length 25 mm. Panama City, Panama. × 6.6.

Fig. 5. *O. occidentalis.* Right abdominal appendage, right lateral view. Carapace length 25 mm. Chamela Bay, Mexico. × 9.2.

Fig. 6. *O. albicans.* Right abdominal appendage, right lateral view. Carapace length 24.5 mm. Bermuda. × 6.4.

FIG. 1

FIG. 2.

ON THE GROWTH AND ECOLOGY OF BRACHYURAN CRABS OF THE GENUS OCYPODE

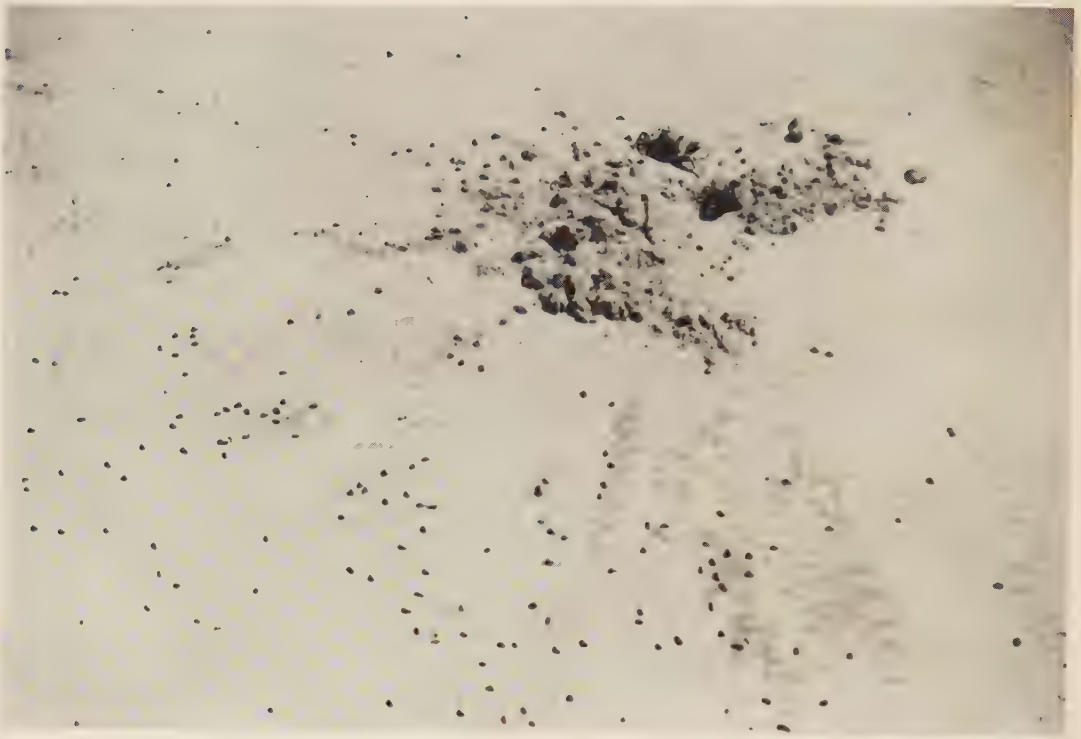


FIG 3

FIG. 4.

FIG. 5.

FIG. 6.

ON THE GROWTH AND ECOLOGY OF BRACHYURAN CRABS OF THE GENUS OCYPODE.

30.

High Speed Photographs of Flying Fishes in Flight.

H. E. Edgerton
Massachusetts Institute of Technology

&

C. M. Breder, Jr.
New York Aquarium

(Plates I–VIII).

Introduction.

The study of the mechanism of flight of the Exocoetidae has long been handicapped by a lack of good photographs of the performance. Such knowledge as we have of the factors involved has been based on simple observation and the interpretation of studies on the morphology of the Exocoetidae. That this was still in a not altogether satisfactory state led Breder (1937 and 1938) to remark rather sharply about the general attitude on the problem. Further no one can deny that there are still a host of details, a knowledge of which would be both of practical aerodynamic and academic value.

The first satisfactory photographs of flying fishes in various stages of flight are presented herewith with such interpretations as may be made from them. The photographs were taken on the east coast of Catalina Island, California, at night, during July, 1940, by one of the authors, Edgerton. They all represent the species *Cypselurus californicus* (Cooper) and are all results of the high-speed electrical flash photography method developed at the Massachusetts Institute of Technology. The value of this device for biological pursuits concerning locomotor matters involving high speeds is obvious. See Edgerton & Killian (1939) for a comprehensive bibliography on technique. If it had been practicable, high-speed motion pictures would have been even more valuable and it is to be hoped that such may be made in the future. As it is the stills presented herewith show a host of items unsuspected and illuminate a variety of others which for long have resided in the limbo of half-knowledge. The time of exposure in all cases is about 1/10,000 of a second, which is sufficiently short to "stop" all motion.

Acknowledgment is made of the splendid cooperation of the Catalina Island Company which furnished the motor boat *Blanche W*. This ship is equipped with a 110 volt D. C. generator and search light for observing the flying fishes at night. A small converter was used to produce alternating current to operate the electrical flash equipment. Two flash lamps were used in parallel. One of these was an experimental lamp about four feet in length (in two sections) in a cylindrical reflector. The other was a spiral lamp in a spherical reflector that was loaned for the occasion by the Los Angeles *Herald-Express*.[1] The straight tube was mounted on a pipe-work frame as far out over the water as possible, while the other was hand-held and directed at the fish that was photographed. A miniature Speed Graphic camera was used. A photograph is shown of the entire arrangement on the foredeck of the *Blanche W* in Plate I, Fig. 1.

Analysis of Plates.

The details which these photographs show are analyzed in the following section while the resulting interpretations are given under the heading "Discussion," both the remarks and interpretations being those of Breder.

Plate II, Fig. 2. The fish in full flight. Since the right pectoral is evidently arched upward near its center of pressure it would appear that the fish is rolling to that side with the left pectoral high. At the same time the tail is being swung to the right as is evidenced by the weaker central rays bending to the left. This would then represent normal resistance to extrinsic turning with banking to the right. Since the effects are

[1] This second lamp is the same as the Eastman Kodatron Speedlamp.

both slight, as is evident, it should represent an incipient turn of large radius which is being corrected. It may be noted that the right pelvic also appears to be pressed upwards with the left normal. The dorsal fin so far as can be seen in this picture seems unaffected. This shows well the extent of expansion of the wing surfaces under actual flight. Dead and preserved material give the impression of much less wing area due to shrinkage of the delicate membrane between the supporting ribs.

Plate III, Fig. 3. Just before emergence the paired fins may be seen closely appressed to the sides, while the upper caudal lobe already raises a wake, throwing spray high in the air before the head of the fish breaks the surface.

Plate III, Fig. 4. Similar to Fig. 3 but with even greater spray throwing and the fish describing a curve. It is doubtful if this attempt actually lead to a flight.

Plate IV, Fig. 5. Two fish just at emergence. The pectorals are lifted but the pelvics seem to be only about half extended. At the extreme left are to be seen the first few flicks of spray raised by the upper caudal lobe. The emergence of the snout and body is represented by the heavy mass of spray. Note the extent of travel by the fish before the earliest spray has fallen.

Plate IV, Fig. 6. Full lateral view of a fish just before taking off. Both pectorals show a large amount of arching due to the pressure on them just before flying speed is obtained. The pelvics are only partly, if at all, unfolded. When this occurs the tail lifts and the greater amount of supporting surface relieves the load on the pectorals.

Plate V, Fig. 7. A diagonal view of a fish about to take off. The one visible pelvic appears to be about one-half expanded. Note the zigzag track which marks the "taxi" period and gives some idea of the value of each tail thrust in terms of the fish's length.

Plate VI, Fig. 8. A fish coming head on while in the "taxi" period. Apparently the pelvics are still being held close to the body for, if otherwise, in this photograph they should be conspicuous. As usual during this time the fish appears to be rolling badly, at the moment bearing down on the right pectoral and lifting the left. As some measure of the vigor of this rolling movement the flexible posterior margin of this fin is clearly bending down as the fin presses upward. It is this rolling that has given rise to the oft-repeated claim of wing flapping flight in these fishes.

Plate VII, Fig. 9. A fish just having cleared the water and steadying off to a smooth glide. The pelvics are still at a sharp angle pressing the tail upward. A moment later they would be approximately parallel to the pectorals.

Plate VII, Fig. 10. A second view of essentially the same position as that of Fig. 2 but not as marked a turning. The left pectoral of this fish has been damaged on its posterior border. Another specimen in the background is just leaving the water with the long lower caudal lobe still immersed.

Plate VIII, Fig. 11. A fish not quite maintaining flying speed. The body is somewhat arched in a vertical plane anticipatory to the tail's touching the surface of the water, when the "taxi" stage will be resumed and flight continued without complete submergence.

Discussion.

The photographic evidence here recorded is in good agreement with recent descriptive interpretation, *e. g.* Breder (1930), Hubbs (1933, 1935 and 1937), Carter & Mander (1935), Forbes (1936), and Loeb (1936). Reference to these papers shows that nearly all of the descriptive details given by them are evident from these photographs. In addition there are a number of items that could not be made out by field observation or interpretations based on anatomical study.

For example, in Figs. 6, 7 and 8 it may be seen that the mouth is held open. In all the others this feature cannot be distinguished because of position or some other reason. If this can be taken to mean that flying fishes usually or normally hold their mouths open during flight it is to say the least surprising. Even that they ever do was not expected. Two reasons for holding the mouth closed would be to preserve intact the streamline form of the head and to prevent the desiccating effect of a current of air passing over the delicate gill membranes. However this may be it is clear that these fishes do not always preserve form and conserve moisture by this simple expedient.

The two pictures of Plate III showing the fishes completely submerged and swimming nearly parallel with and very close to the surface indicate another unexpected feature; that of throwing spray with their tails before breaking the surface. All this happens so quickly that under mere ocular observation it is normally lost in the general flurry of the fish's plunging out into the air. Checking back, however, the proportions of these fish are such that the upper caudal lobe would project through the surface if they were swimming close to and parallel to it. Actual measurements show that the tail tip of a *Cypselurus californicus* 12 inches in standard length is a little over ¾ inch above the level of the flat back while the dorsal fin when erect is not quite ½ inch above the back. In other words a fish 12 inches long would be just breaking the surface film with its tail tip when swimming with ¾ inch of water over its back. This would seem to indicate that these fishes travel in this fashion just prior to emerging for some little distance, for otherwise it would be very unlikely that the photographer could get such photographs at all. Their sometimes apparent relatively steep angle of emergence is then probably generally due to the rapid tip up of the snout as the unfolding wings encounter air resistance. An angle of emergence of more than about 4° would prevent the tail and dorsal from breaking

the surface before the snout came out. Incidentally these photographs show very good agreement with the sketches of Hubbs (1933).

In considering the various flexures of the fin rays that are shown in these photographs it must be borne in mind that these are long, thin, more or less flexible rods that are attached only at their bases and there operated by relatively small muscle bundles. Since the fish can only wave these rods about in various ways, mostly backward and forward and to a lesser degree up and down and since they have no voluntary control over the curvature of them it follows that the contortions shown are the result of wind pressure. This being the case the interpretation of the meaning of the curves seen becomes relatively simple. Even, as in these cases, where we have no direct knowledge of what the fish was doing before or after the instant of exposure, these curves, as indicated under "Analysis of Plates," give clues as to what the fish was undertaking.

In Fig. 11, for example, it is clear that the fish is descending and is all set for a renewal of the "taxi" period. Note that the wings are relatively straight and show a large lateral dihedral, for stability, while in Fig. 6, where the fish is driving ahead under the impulse of powerful tail thrusts, the wings held at a lower angle (see the basal part) are actually blown back and up and cupped by wind pressure. In other words they are loaded relatively more heavily than, as in Fig. 11, where the fish is merely falling freely.

Many other points already fairly well understood are reinforced by the details in these photographs. The next logical step looking toward a further clarification of exocoetid flight would be the application of high-speed cinematography whereby actual series of steps in this performance could be studied. Carter & Mander (1935) used motion picture technique to check the speed of flight but presumably they obtained a very small image not of value in studying details of manipulation of the fishes' structures.

Recently Woodcock (1940a and 1940b) has discussed the instability of air over the ocean showing that bands of updraughts occur, by an ingenious noting of the differential behavior of soaring gulls. These bands are responsible for the lines of Sargassum commonly found in the Atlantic according to the studies of Langmuir (1938). Since exocoetids may fly in a straight line or in various curving flights it may well be that these too are taking advantage of such atmospheric characteristics instead of merely being blown off their course as has been generally assumed. Carter & Mander (1935) indicated that they found their fish flying greater distances over rough water than over smooth and inferred that advantage was taken of the greater air turbulence in the former condition. Hubbs (1933 and 1936) could not find a difference in duration of flight to be correlated with travel over smooth or rough water. In any case the situation calls for a study of the flight of these fish in the light of the work of Woodcock on gulls and in reference to the general recent advances of micrometerology.

Bibliography.

Breder, C. M., Jr.

1930. On the structural Specialization of Flying Fishes from the Standpoint of Aerodynamics. *Copeia*, No. 4: 114–121.

1937. The Perennial Flying Fish Controversy. *Science* **86** (2236): 420–422.

1938. A Contribution to the Life Histories of Atlantic Ocean Flyingfishes. *Bull. Bingham Oceanographic Coll.* **6** (5): 1–126.

Carter, G. S. & Mander, J. A. H.

1935. The Flight of the Flying-Fish, Exocoetus. *Rep. Brit. Assn. Adv. Sci.*, **105**: 383–384.

Edgerton, H. E. & Killian, J. R.

1939. Flash. Hale, Cushman & Flint. Boston.

Forbes, A.

1936. Flying Fish. *Science*, N. S., **83**: 261–262.

Hubbs, C. L.

1933. Observations on the Flight of Fishes, with a Statistical Study of the Flight of the Cypselurinae and Remarks on the Evolution of the Flight of Fishes. *Pap. Mich. Acad. Sci., Arts and Letters*, **17**: 575–611.

1935. Nature's Own Seaplanes. *Smiths. Rep.*, **1933**: 333–348.

1937. Further Observations and Statistics on the Flight of Fishes. *Pap. Mich. Acad. Sci., Arts and Letters*, **22**: 641–660.

Langmuir, I.

1938. Surface Motion of Water Induced by Wind. *Science*, **87**: 119–123.

Loeb, L. B.

1936. The "Flight" of Flying Fish. *Science*, N. S., **83**: 260–261.

Woodcock, A. H.

1940a. Observations on Herring Gull Soaring. *Auk.* **57**: 219–224.

1940b. Convection and Soaring Over the Open Sea. *Jour. Mar. Res.* **3**: 248–253.

EXPLANATION OF THE PLATES.

Photographs by Dr. H. E. Edgerton. Taken at night by means of a Kodatron type of electrical flash lamp. Photographs all unretouched. All specimens are *Cypselurus californicus* (Cooper).

Plate I.

Fig. 1. The photographic equipment and its arrangement as used for taking pictures of flying fish in flight.

Plate II.

Fig. 2. A fish in full flight. The object in the upper left corner is part of the special illuminating device.

Plate III.

Fig. 3. Just before emergence, showing that the water is splashed before the fish breaks the surface.

Fig. 4. A more advanced stage in the water splashing period.

Plate IV.

Fig. 5. Two fish just about to leave the water near the end of the "taxi" stage.

Fig. 6. Full lateral view of a fish in the "taxi" stage.

Plate V.

Fig. 7. A diagonal view of an advanced "taxi." Note the trail left by the oscillating tail.

Plate VI.

Fig. 8. Head on view of a fish in an advanced "taxi." Note the evidences of roll in the differentially warped wings.

Plate VII.

Fig. 9. Just as the tail raises after the "taxi" stage.

Fig. 10. One fish in full flight in the foreground. Note the torn left wing. Another in the background with only the long lower caudal lobe immersed.

Plate VIII.

Fig. 11. Losing flying speed and about to dip the tail in the water for a resumed "taxi."

FIG. 1.

HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT.

FIG. 1

HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT

FIG. 3

FIG. 4

FIG 5

FIG 6

HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT.

FIG 7

HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT.

FIG 8
HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT.

FIG. 9

FIG. 10.

HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT

FIG. 11.

HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT.

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